Ex. #2 - Results for Boston SP.769 PV Solar Energy Systems Fall 2004

You are to take your analysis of "clearness index" a step further to determine the monthly average, total daily solar energy flux (kwh/m^2) onto a surface tilted up at an angle equal to *the latitude* of your chosen site.

Start from the total horizontal values available on the web, but now use the 30 year averages of monthly values for your site.

Use the approximate relations in the handout for computing monthly average, daily values on the tilt, $\bar{H}_\beta$, namely:

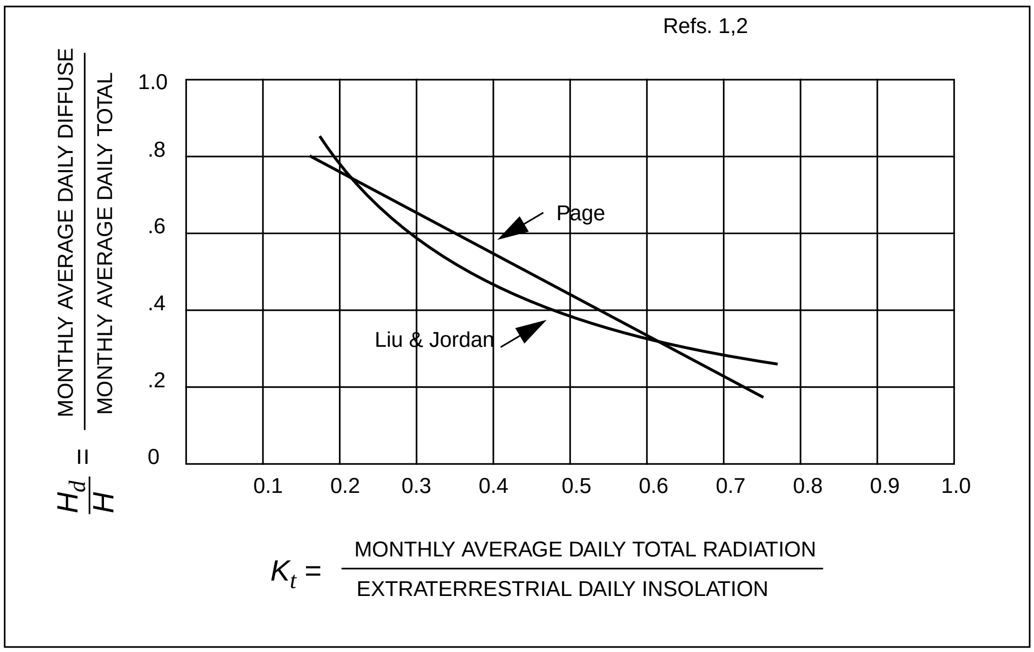
$$\bar{H}_\beta = R \cdot \bar{H}$$

where

$$R = \left[1 - \left(\frac{\bar{H}_d}{\bar{H}}\right)\right] \cdot R_b + \left(\frac{\bar{H}_d}{\bar{H}}\right) \cdot \left(\frac{1 + \cos\beta}{2}\right) + \rho \cdot \left(\frac{1 - \cos\beta}{2}\right)$$

The first of these states that the monthly-average, daily total radiation incident on a *surface inclined at an angle* β is given by the product of two factors: the monthly-average, daily total radiation incident on a *horizontal surface at the earth's surface* and a coefficient *R* defined by the next equation.

In this, $\bar{H}_d/\bar{H}$ is the ratio of the monthly-average, daily diffuse radiation to the monthly average, monthly-average, daily total radiation incident on a horizontal surface - determined from the graph below, knowing the sites clearness index, (which you should re-compute for each month).



R_b is the ratio of the monthly-average *beam radiation on the tilted surface* to that on a horizontal surface. R_b is then "estimated" to be the ratio of total, daily, direct extraterrestial radiation on the tilted surface, what we labeled $H_{ext}(\beta)$, to that on a horizontal surface, H_{ext},:

$$R_b = \frac{H_{ext}(\beta)}{H_{ext}} = \frac{\cos\delta\cos(\lambda - \beta)[\sin\omega'_{ss} - \omega_{ss}'\cos\omega_{ss}']}{\cos\delta\cos\lambda[\sin\omega_{ss} - \omega_{ss}\cos\omega_{ss}]}$$

In this ω'_{ss} is the sunset hour on the tilted array while ω_{ss}, without the prime, is the sunset hour on the horizontal - equations for which you have in the handout (call me if you have a question here).

For Boston, $\lambda = 42.2^o$

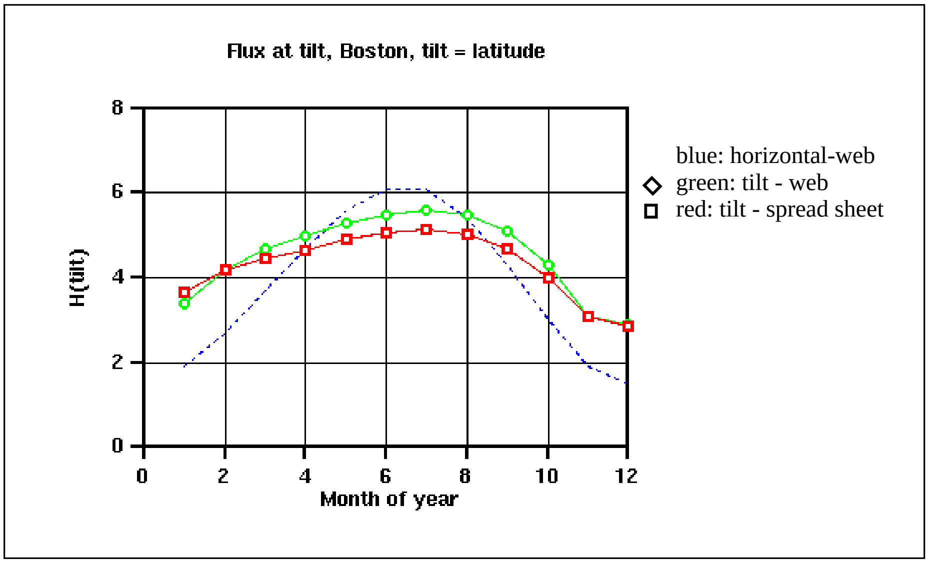
month midday	*decln*	*mega*[a]	*Hext*(β)	*Hext*	*Rb*	*H Web*	K_t	H_d/H	*R*
15	**-21.3**	**1.21**	**9.61**	**3.62**	**2.65**	**1.9**	**0.525**	**0.407**	**1.93**
45	**-13.6**	**1.35**	**10**	**5.04**	**1.99**	**2.7**	**0.535**	**0.395**	**1.55**
75	**-2.42**	**1.53**	**10.3**	**7.18**	**1.44**	**3.7**	**0.515**	**0.418**	**1.2**
105	**9.41**	**1.72**	**10.2**	**9.4**	**1.08**	**4.7**	**0.5**	**0.435**	**0.99**
135	**18.8**	**1.88**	**9.76**	**11.1**	**0.881**	**5.6**	**0.505**	**0.429**	**0.876**
165	**23.3**	**1.97**	**9.47**	**11.9**	**0.799**	**6.1**	**0.514**	**0.419**	**0.829**
195	**21.7**	**1.94**	**9.58**	**11.6**	**0.827**	**6.1**	**0.527**	**0.405**	**0.845**
225	**14.4**	**1.81**	**9.99**	**10.3**	**0.968**	**5.4**	**0.524**	**0.408**	**0.928**
255	**3.42**	**1.62**	**10.3**	**8.29**	**1.24**	**4.3**	**0.519**	**0.414**	**1.09**
285	**-8.48**	**1.44**	**10.2**	**6.02**	**1.69**	**3**	**0.498**	**0.437**	**1.33**
315	**-18.2**	**1.27**	**9.8**	**4.19**	**2.34**	**1.9**	**0.454**	**0.488**	**1.62**
345	**-23.1**	**1.17**	**9.48**	**3.29**	**2.89**	**1.5**	**0.456**	**0.484**	**1.91**

a. I do not show the column values for sunrise/sunset hour on the panel at tilt since it is $\pi/2$ radians each day of the year.

month of year	*H*(β)	*H*(β) *Web*	
1	**3.66**	**3.4**	
2	**4.18**	**4.2**	
3	**4.44**	**4.7**	
4	**4.65**	**5**	
5	**4.91**	**5.3**	
6	**5.06**	**5.5**	
7	**5.15**	**5.6**	
8	**5.01**	**5.5**	
9	**4.68**	**5.1**	
10	**4**	**4.3**	
11	**3.08**	**3.1**	
12	**2.86**	**2.9**	

A plot of these last two columns is shown below. Also show is the way the monthly average, total daily flux on the horizontal varies from month to month.

Results for Boston:



It would be wise to show uncertainty bands for each month of the year.

EC.S07 Photovoltaic Solar Energy Systems
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